42. Notes on Turacin and the Turacin-Bearers. By Sir Arthur H. Church, K.C.V.O., F.R.S.*

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In bringing, at the suggestion of the Secretary, these notes before the Zoological Society I have a threefold object. First, to give a summary history of our knowledge of the occurrence in the Plantain-eaters of turacin, the remarkable (I may say, the unique) decorative pigment which is distinctive of the three genera *Musophaga*, *Turacus*, and *Gallirex*; secondly, to describe the properties of the pigment; and, thirdly, to correct some prevalent errors on the subject of turacin—errors due in part to initial mistakes made by observers, and in part to incorrectness in the transmission of facts by copyists.

Although the earliest observation as to the occurrence in certain Turacoes of a singular red pigment seems to be assignable to the year 1818, yet I have not found any publication of the fact by the original observer until more than half a century later. Then, on January 17th, 1871, a Corresponding Member of this Society, M. Jules Verreaux, described at a meeting his observations and experiments on the subject, referring them back to the year 1818. Verreaux's remarks are to be found in the 'Proceedings of the Zoological Society' for 1871 (pp. 40 *et seq.*); they refer to the *Corythaix albicristata* of Strickland. Many of these Turacoes were met with in the Knysna district of the Cape of Good Hope, and were carefully observed by Verreaux. He noticed that, in the torrential rains that prevailed at the time, these birds left the tree-tops and sought refuge in the dense lower branches. One bird, which he had seized by the wing, escaped, and he says that great was his surprise to see the inside of his hand coloured a blood-red. Some days later the experiment was repeated with three more specimens caught in a soaked condition; it was easy to remove the pigment from the feathers by friction and to reduce them to a pale rose hue. What M. Verreaux here adds to his observation as to the solubility of the red pigment in rain-water is, I venture to think, hard to believe. He wrote in French, and I give his own words:—"Mais ce qui nous surprit le plus, fut de voir cette même coloration rouge vif revenir dès que l'oiseau était complètement séché. Nous avons renouvelé cette opération deux fois par jour, et chaque fois nous avons eu le même résultat." M. Verreaux further extends his observations to other species of Turacoes, finding in them the same colouring-matter, possessed of the same mobility and of the same power of renewal when the feathers became dry. He even affirms such recovery of colour in the case of birds that have been killed as well as of those that have been captured. One cannot

* Communicated by the Secretary.

but ask, how is it possible for a mature feather to be again supplied with this localized red pigment after it has lost its original charge and after the vessels in the quill have dried up, their function having been fulfilled? The opinion of V. Fatio, as to an oil making its way up the mature feather and dissolving and distributing pigmentary deposits already present, does not apply to turacin which is insoluble in oily media. As to the case now being considered, I have not been able to obtain any confirmation of this renewal of the pigment (apart from a moult) from any trustworthy naturalist. The late J. J. Monteiro, the late Dr. Benjamin Hinde (of Bathurst on the Gambia), and many other competent observers of these birds in their native haunts and in captivity have expressed themselves strongly on this point. It may be admitted that in the folded pinion which has had its pigment moved by soaking, some of the red solution may travel from the feathers beneath to the surface as it dries; thus we should have a case of transference of pigment, not of its renewal.

Amongst those who, after Verreaux, have observed this want of fixity in the red pigment of the Turaco I may name the late Rowland Ward, the late W. B. Tegetmeier, also J. J. Monteiro and Dr. B. Hinde. The last-named, in a letter dated May 1865, said the moment soap touches the feathers the colour runs, although it is difficult of extraction by pure water. But he added "the birds which I sent home washed themselves nearly white in the water given them to drink." In my memoir of 1869, I mentioned Mr. Tegetmeier as having introduced the subject now being discussed to my notice. His own attention had been drawn to the matter by a correspondent of 'The Field,' who sent him a washed-out feather. Mr. Tegetmeier forwarded this feather to me and asked me to ascertain if there were any possibility of its having been dyed.

Such, in brief, was the position of the problem when in 1866 I began my researches. The chief results of these were published in the Phil. Trans. of 1869 and 1892, while in 1894 a Friday Evening Discourse in the Royal Institution presented a digest of the whole enquiry *. Although it would be unbecoming in me, a chemist, to enter into classificatory questions before a company of zoologists, I may venture to remind you that, according to many systematists, the Order Cuculiformes includes two suborders of equal rank, the Cuculidæ or Cuckoos and the Musophagidæ or Plantain-eaters. The former is an extensive suborder and cosmopolitan in range, while the latter contains less than 40 species and is confined to the Ethiopic region of Continental Africa. Of

* "Turacin, a new Animal Pigment containing Copper," 'Student,' i. (1868) pp. 161–168; with a coloured plate.
"Researches on Turacin, an Animal Pigment containing Copper," Phil. Trans. clix. (1869) pp. 627–636 (with 4 figs. of spectra).
"Researches on Turacin, an Animal Pigment containing Copper," Part II., Phil. Trans. clxxxii. A. (1892) pp. 511–530 (with 9 figs. of spectra).
Proc. Roy. Inst. xiv. (1894) pp. 44–49.

the six genera of Musophagidæ three contain the crimson pigment which I named turacin. These are:—*Musophaga*, 2; *Turacus*, 21; *Gallirex*, 3; or 26 turacin-bearers in all. The three remaining genera from which turacin is absent are:—*Corythæola*, 1; *Chizærhis*, 4; and *Gymnoschizorhis*, 2; or 7 in all. There are two remarks that may be interposed in this connection. The first is that the crimson pigment is identical in all the species, and occurs not only in from 6 to 18 of the primary and secondary pinion-feathers, but also in all other similarly-coloured feathers or parts of feathers which are found on some of these birds—for example, in the head-feathers of *Musophaga violacea*, in the crest-feathers of *Turacus donaldsoni*, *T. fischeri*, and *T. meriani*, and in the head-feathers of *Gallirex johnstoni* behind the crest. The second remark refers to the pinion-feathers of three out of four species of *Chizærhis*, which have white patches bare of any pigment pretty much in the same position as the crimson patches in the turacin-bearers, although mostly confined to one side of each shaft—a curious coincidence, at all events.

I may now turn to the properties of turacin. We have already seen that it is soluble in water. Not, we may add, in hard water, but in clean rain water or, better, in distilled water. It is still more easily dissolved by weak alkaline liquids, extremely dilute ammonia being the best solvent. From this crimson solution, the colouring-matter, the turacin, is precipitated as gelatinous flocks on neutralization by hydrochloric or other acid. The flocks that separate when collected and dried form a deep red amorphous mass, crimson by transmitted light when in thin layers, but exhibiting a surface-lustre of a purplish hue, not unlike that reflected from crystals of potassium permanganate. Thus the appearance of solid turacin cannot be said to be accurately described when it is spoken of as "a metallic red or blue powder," as in the Enc. Brit. 11th ed. vol. x. p 226 *a*. Turacin is insoluble in alcohol, ether, chloroform, petroleum-spirit, benzol, and the usual solvents of resins and oils. In order to obtain it in a pure state special procedure is required to prevent its contamination with the natural oil of the feathers, while it is not possible to free it completely from all traces of non-essential mineral matter. The action of heat on dry turacin presents several points of interest. It suffers no change at a temperature rather above that of boiling-water, but at or near the boiling-point of mercury it is profoundly modified without loss of weight and becomes insoluble in alkaline liquids. If this altered turacin be now exposed to a high temperature in the presence of air its combustible constituents burn away, leaving a black ash, amounting in the purest samples to about 9·8 per cent. of the original weight. This ash consists almost entirely of oxide of copper, the amount corresponding to at least 7 per cent. of that metal in the turacin itself. Here again the statement in the Enc. Brit. (*loc. cit.*) needs correction, for this is a fixed percentage, not one that varies from "5 to 8." In further describing the action of heat upon dry turacin it

must be mentioned that this colouring-matter, when suddenly and strongly heated, yields a volatile, red, copper-containing derivative, which, undissolved by weak ammonia-water, is not only soluble in, but may be crystallized from, ether. It is the vapour of this substance catching fire which gives rise to the green flame so conspicuous when a particle of turacin is heated in the air. If I were discussing the nature and relationships of turacin from a chemical view-point, much would have to be brought forward as to its composition and probable formula. Here let it suffice to say that analysis gives these percentage-numbers:—

Carbon	53·69
Hydrogen	4·60
Copper	7·01
Nitrogen	6·96
Oxygen	27·74

These figures, though deduced from many careful determinations, do not lead unmistakably to one definite empirical formula. With a colloidal compound like turacin, which does not admit of purification by distillation or crystallization, there is always the chance of a disturbing factor being present in the shape of a trace of some impurity. Possibly such an expression as $C_{40}H_{38}N_4CuO_{16}$ is worth suggesting. In this the ratio of nitrogen to metal is as 4 : 1, the same ratio which occurs in hæmatin from blood between nitrogen and iron, and between nitrogen and magnesium in some chlorophyll constituents and derivatives. With all these bodies turacin is also brought into relation when its absorption-spectrum is considered, especially in regard to that broad band in the violet and ultra-violet (between the lines *h* and M) which is common to all these colouring-matters, and which was figured and described by the late Prof. Arthur Gamgee in a paper read before the Royal Society in 1896—a paper in which the author confirms my results, especially those relating to the discovery of turacoporphyrin.

The spectrum of turacin may now engage our attention: in the feather itself the pigmented web shows two broad bands, one with its centre at wave-length at or near 585, the other with its centre near 538. A solution in water containing a trace of ammonia shows the same two bands somewhat shifted towards the violet end of the spectrum; there is also seen a very faint band about the solar line F, but nearly as broad as band No. 2. When turacin which has been precipitated from its alkaline solution by strong hydrochloric acid is again dissolved in weak ammonia-water, and the solution spectroscopically examined, a narrow and faint fourth band situated on the less refrangible side of D makes its appearance. It is almost certain that this band is due to an alteration-product of the original turacin. The two well-marked bands, as they are shown when examining a feather with the spectroscope, closely resemble those of the oxy-hæmoglobin of the blood; while the corresponding bands seen in the

spectrum of an alkaline solution of turacin are not unlike those of CO-hæmoglobin. However, the absorption-spectrum of turacin is sufficiently characteristic to enable one to use it as a criterion of the presence of this pigment in the red feathers of birds. So when Dr. C. F. W. Krukenberg announced the occurrence of turacin in a species not belonging to the Musophagidæ, and not even African, it became necessary to test the assertion. The bird in question is a Cuckoo from the Philippines, *Dasylophus superciliosus*. I obtained a skin, then an assurance of identity from the Bird Department of the British Museum. I removed the sparse red feathers from the head of this Cuckoo and submitted them to spectroscopic scrutiny. They did show an absorption-band, but it was situated midway between the two bands of turacin. Moreover, the colouring-matter, which is orange-red, not crimson, cannot be extracted by ammonia and contains no copper. Hitherto, therefore, turacin has not been found to occur outside the Musophagidæ. It is right to mention here that Dr. Krukenberg's statement as to its occurrence in a *Dasylophus* was made in consequence of a report addressed to him at his request by the authorities of the Senckenberg Museum in Frankfurt, and was not the result of an experiment made by himself*. It has unfortunately found its way into various articles and books, e. g. Enc. Brit. x. p. 226 *a*, where we read "But turacin is not, as was supposed, confined to the feathers of the Plantain-eaters, since it has been obtained from a Cuckoo, *Dasylophus superciliosus*." I have been able to secure a threefold disproof of this statement, for although the occurrence of this pigment in any bird other than a Plantain-eater seemed unlikely, the closely-allied Cuckoos might have supplied an instance.

The occurrence of so large a percentage of copper as 7 in isolated turacin needs a word of comment. It does not imply a large *amount* of this metal in the plumage of a single bird; a high estimate gives less than ·14 of a grain of the metal. And it must be remembered that many recent analyses of vegetable and animal matters show the wide distribution of copper in both kingdoms. Two of the latest researches in this direction were made by Mr. J. W. Dougal† in 1911 and by M. B. Guérithault in 1912‡. In fact, there is no difficulty in accounting for the presence of copper in Turacoes and for its amount.

I purposely exclude from the present paper any discussion of the curious green pigment named turacoverdin by Krukenberg; of the relationships between hæmatoporphyrin and the turacoporphyrin obtained from turacin by the action of acids; and of the supposed synthesis of turacin by treating hæmatoporphyrin with an ammoniacal copper solution.

* C. F. W. Krukenberg, Vergleichend-Physiologische Vorträge (1886), Bd. i. p. 152.

† Pharm. J. 1911 (4) xxxii. pp. 405–7.

‡ Bull. Sci. Pharmacol. 1912, xviii. pp. 633–639.